THE MYSTERIOUS TRANSVERSE WAVES OF 28 JULY

Johnathan Metz and Dale R. Durran
Department of Atmospheric Sciences
University of Washington, Seattle, WA

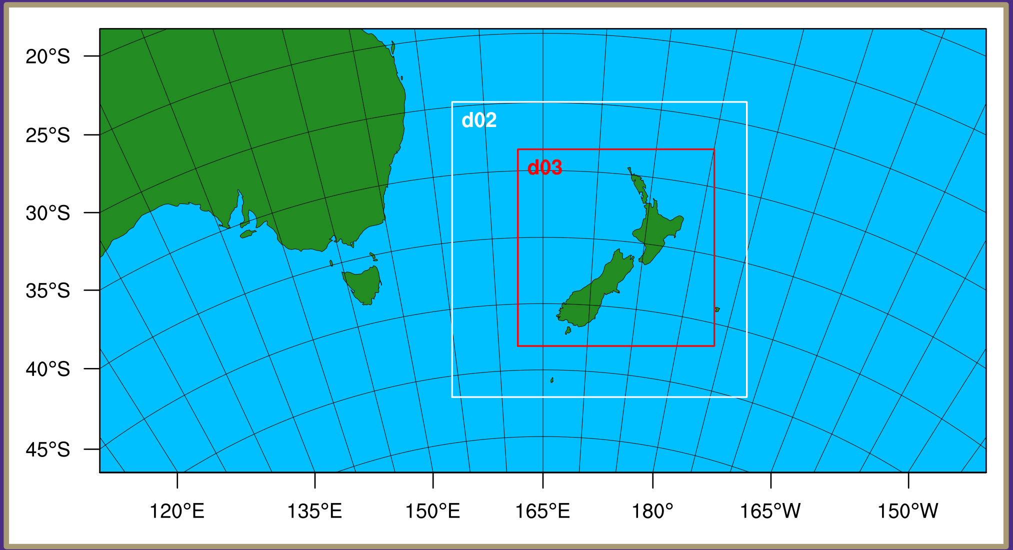
UNIVERSITY of WASHINGTON

Introduction

- 28 Jul case excellent for studying transient wave forcing
- Unfortunately occurred after end of IOPs…so no flight data
- During examination of WRF simulations, we found some interesting features…

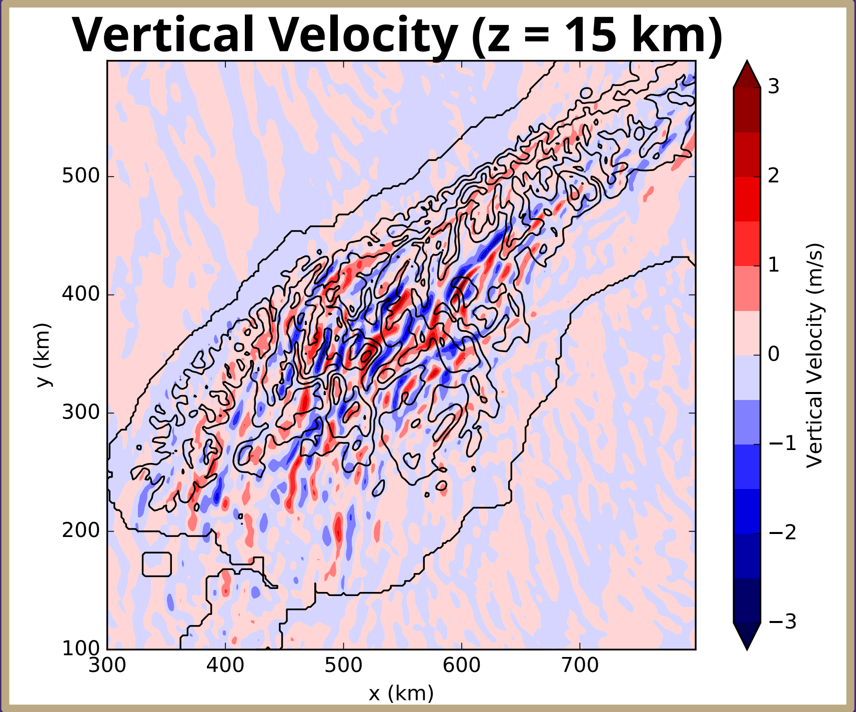
WRF Model Setup

- Real configuration
  - WRF 3.8
  - $\Delta x = \Delta y = 18, 6, 2$ km
  - 108 vertical levels
  - Model top ~ 0.5 hPa



Introduction

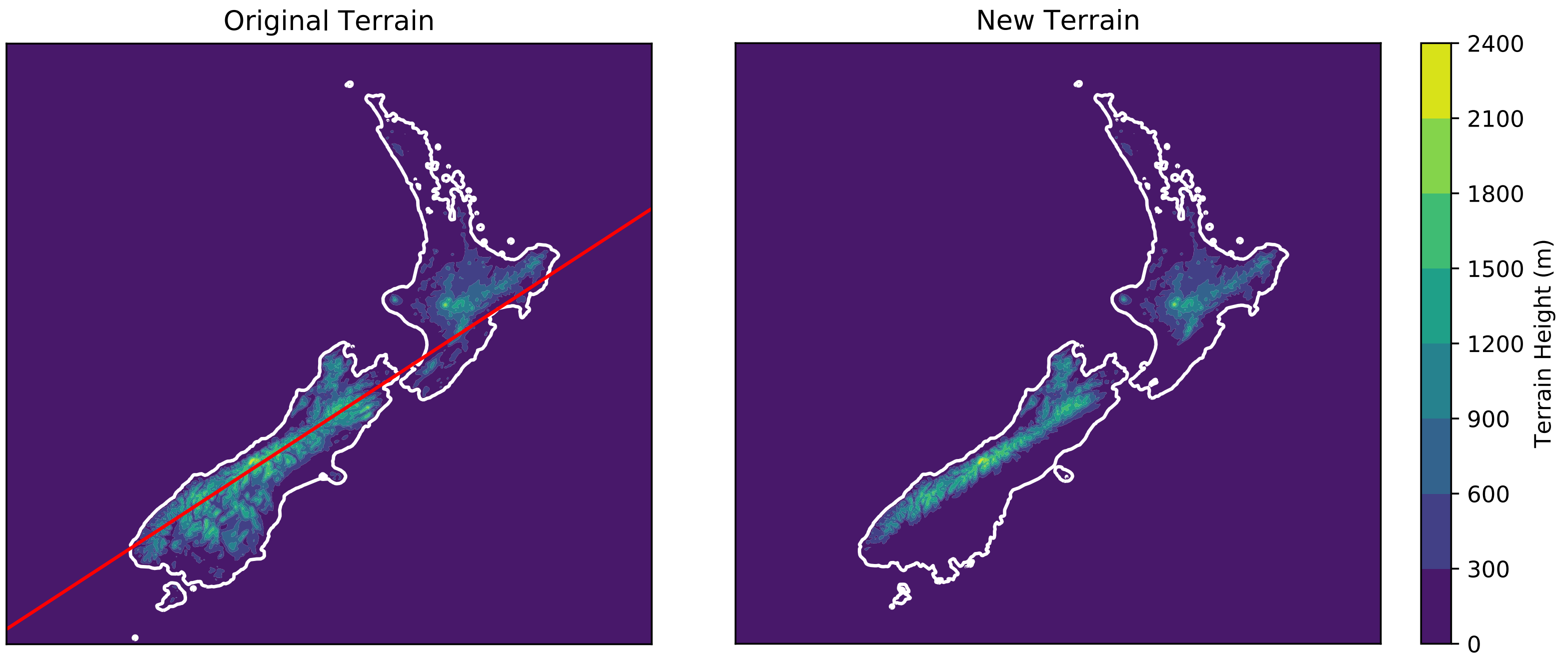
- Waves oriented at an angle to the topography
- Persist for ~15 hr



Possibility #1

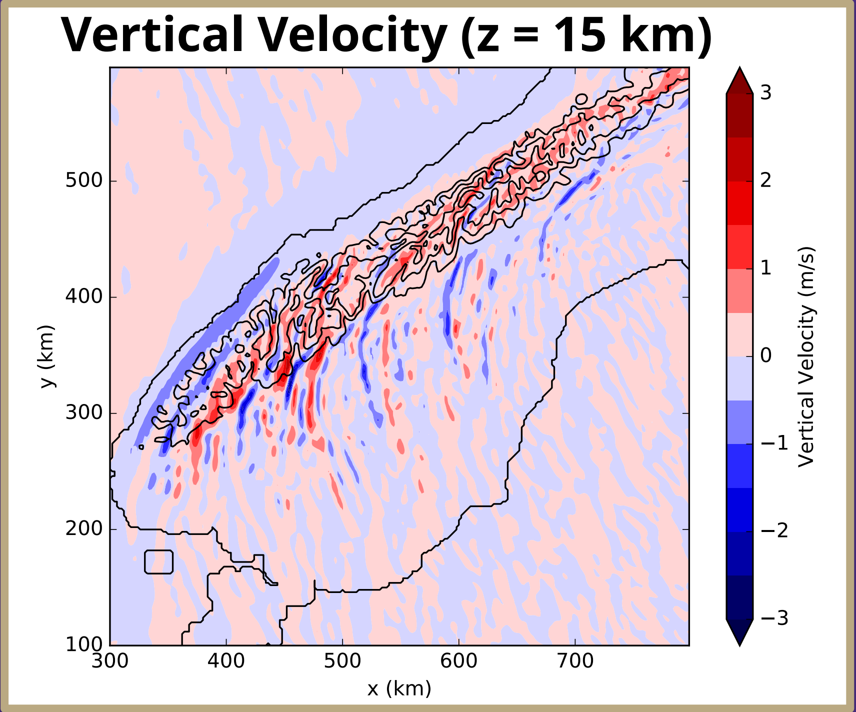
> Waves are due to the lee-side ridges and valleys

Terrain Configuration



“No Lee Ridges”

- Not due to lee side ridges
- Waves are more apparent
- So what is the cause?



Possibility #1

Possibility #1

> Waves are due to the lee-side ridges and valleys

Possibility #1

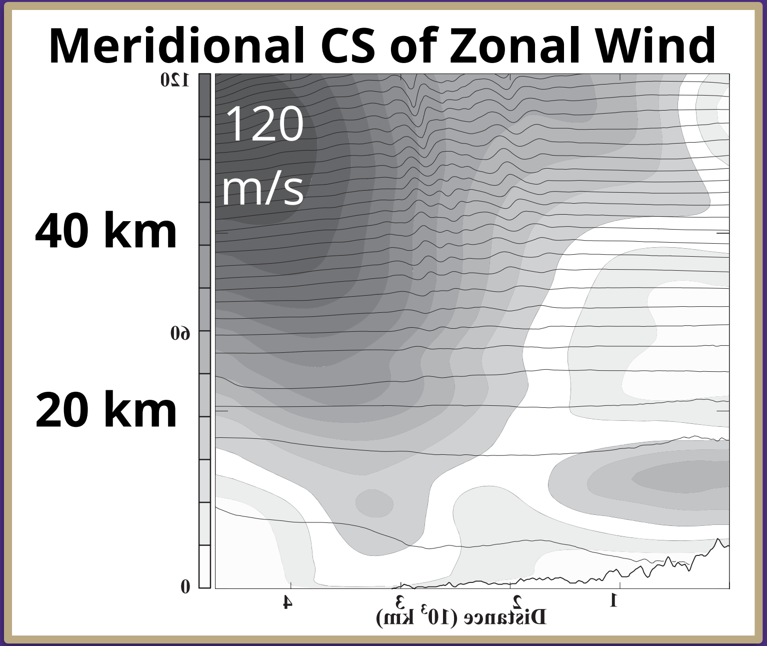
> Waves are due to the lee-side ridges and valleys ✗

Possibility #2

- > Waves are due to the lee-side ridges and valleys ✗
- > Waves are trailing waves à la Jiang et. al. (2013)

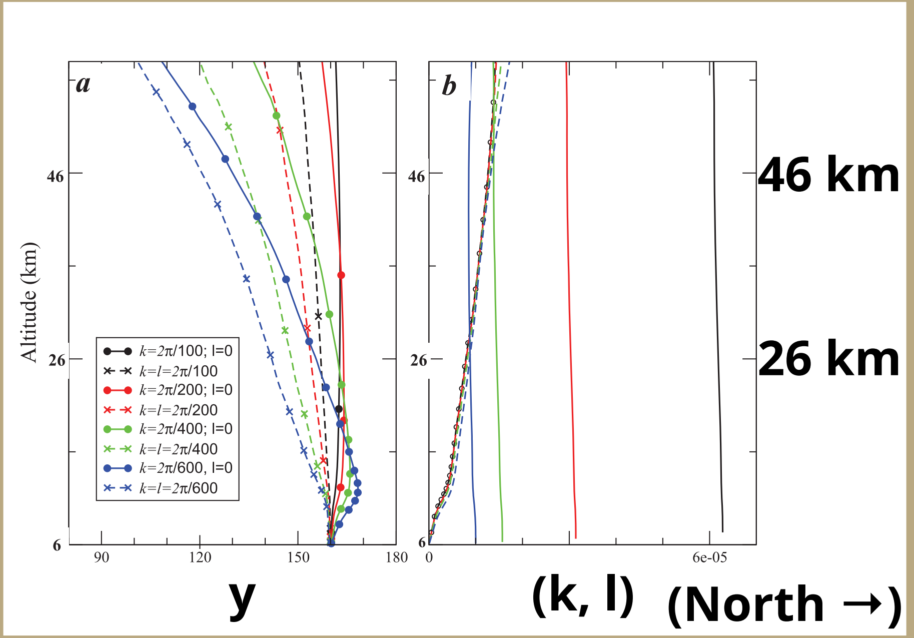
Lateral Shear

> Jiang et. al (2013) demonstrate the formation of transverse waves in the presence of large lateral shear

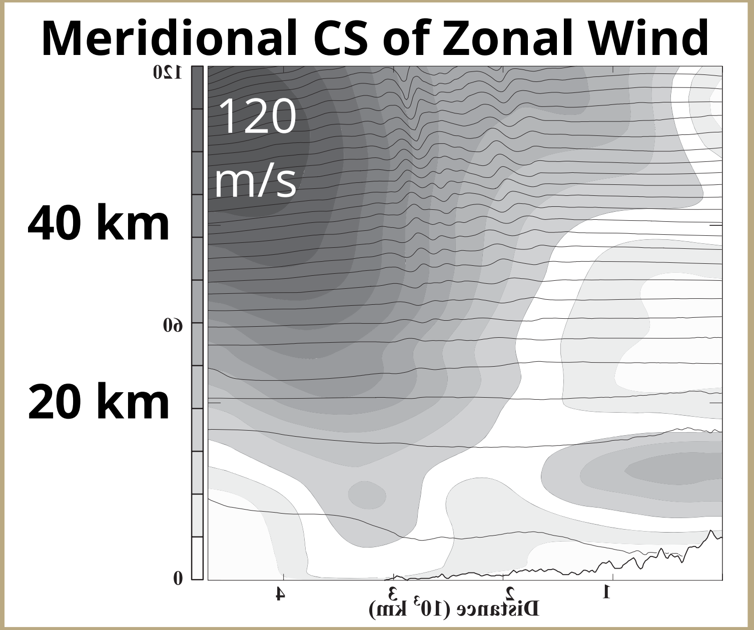


Jiang et. al. (2013)

Lateral Shear

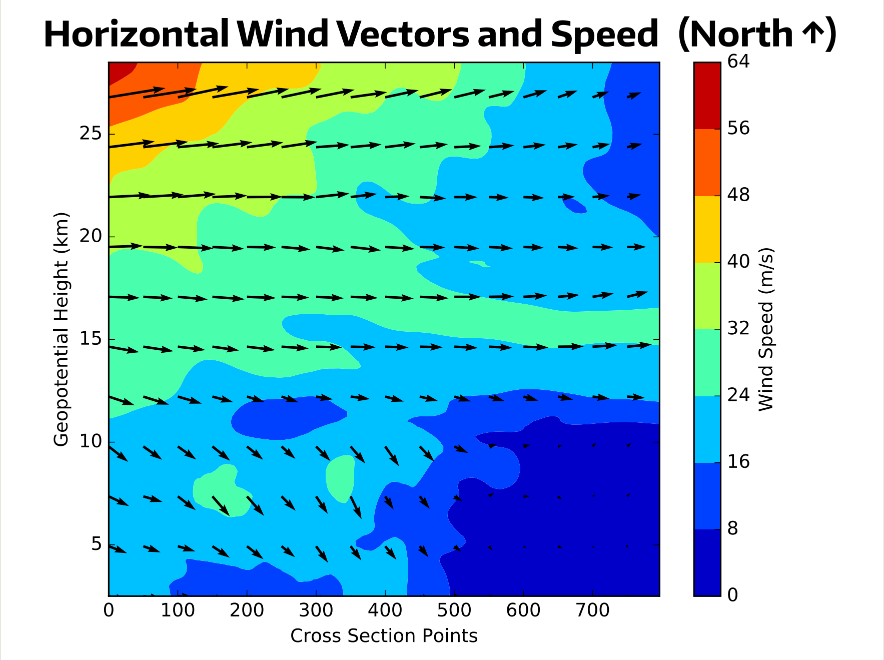


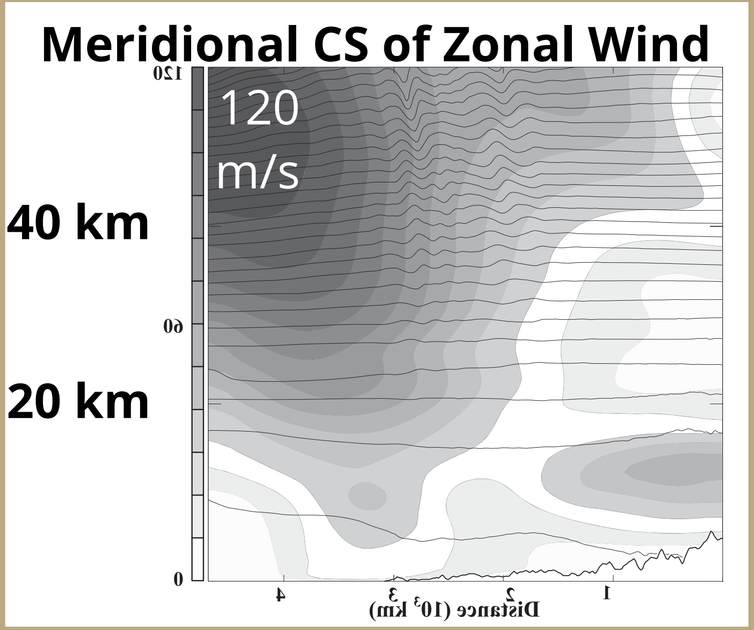
Jiang et. al. (2013)



Jiang et. al. (2013)

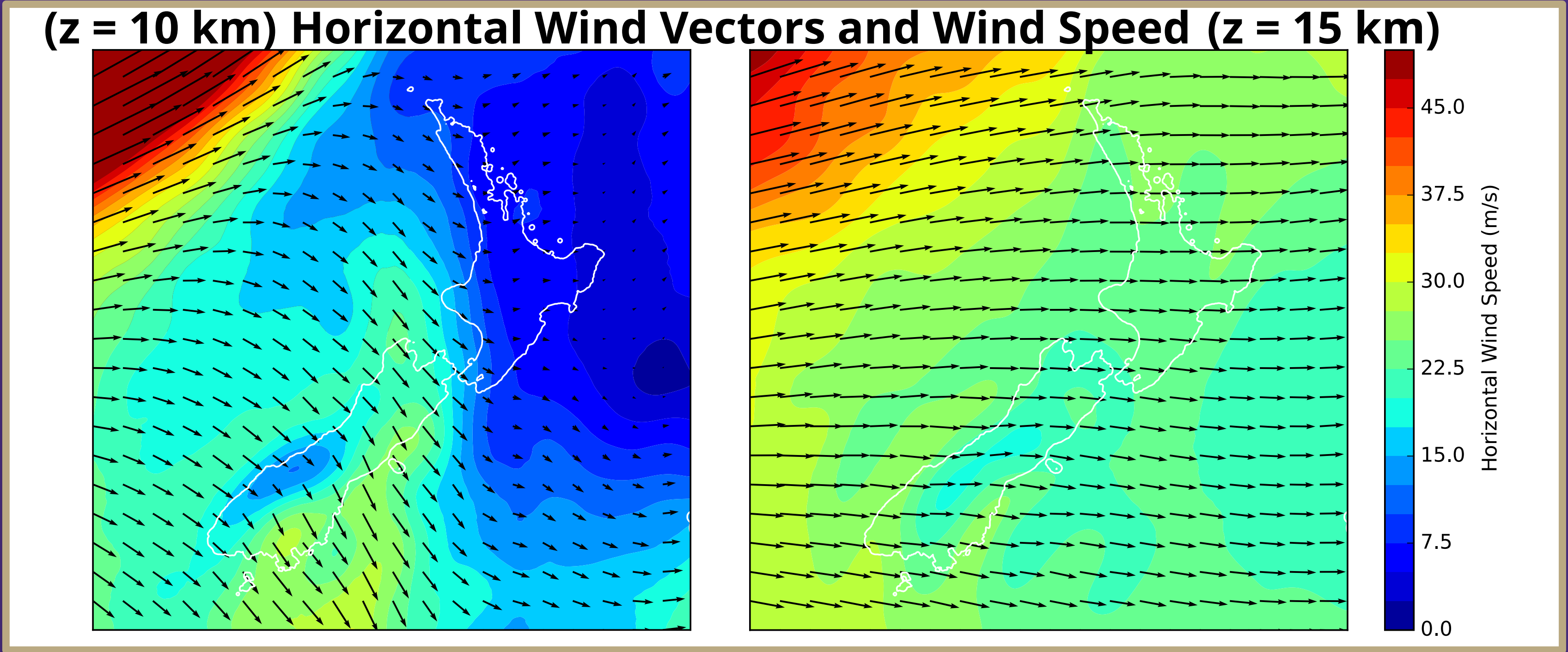
Lateral Shear





Jiang et. al. (2013)

Horizontal Wind Profile



Possibility #2

Possibility #2

- Waves are due to the lee-side ridges and valleys ✗
- Waves are trailing waves à la Jiang et. al. (2014)

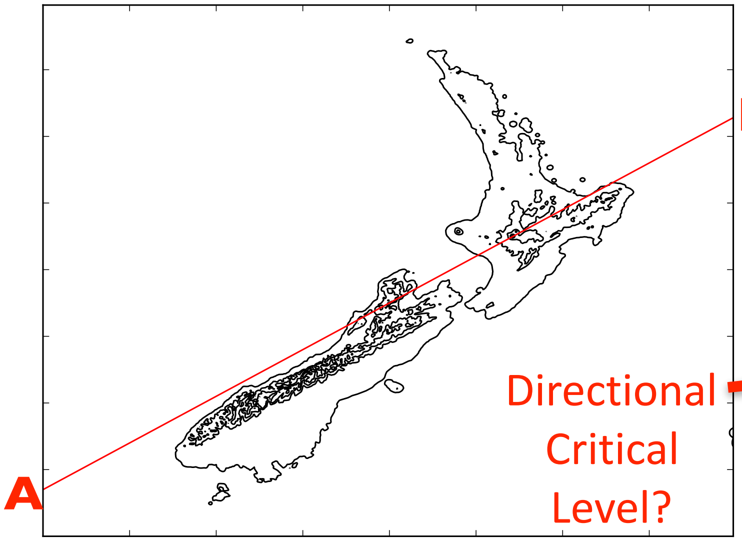
Possibility #2

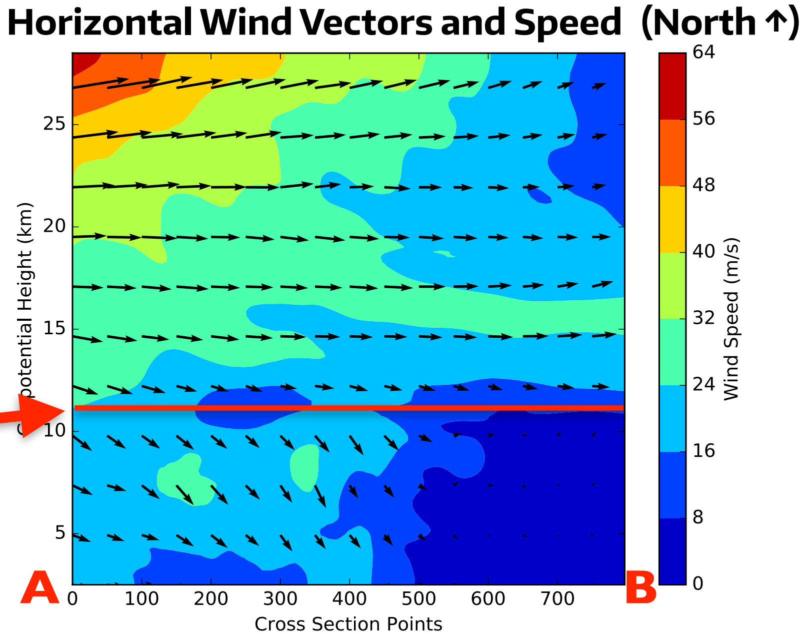
- Waves are due to the lee-side ridges and valleys ✗
- Waves are trailing waves à la Jiang et. al. (2014) ✗

Possibility #3

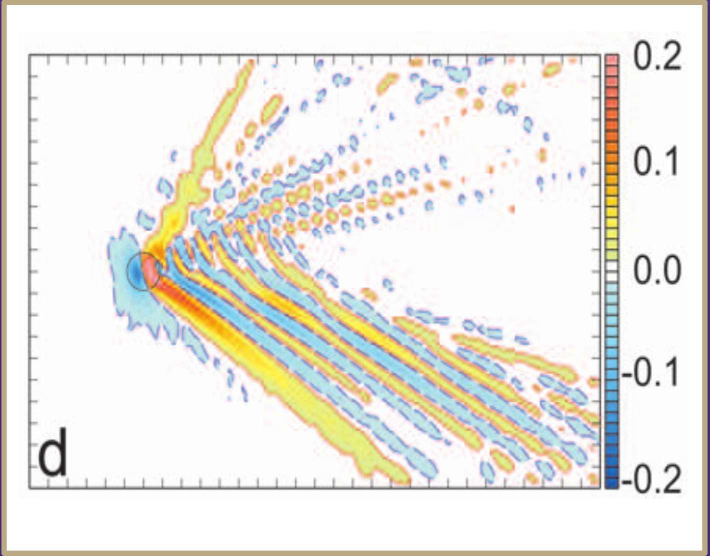
- Waves are due to the lee-side ridges and valleys ✗
- Waves are trailing waves à la Jiang et. al. (2014) ✗
- **Waves are one half of a ship wave pattern, with the other half destroyed by a directional critical level à la Doyle and Jiang (2006)**

Vertical Wind Profile

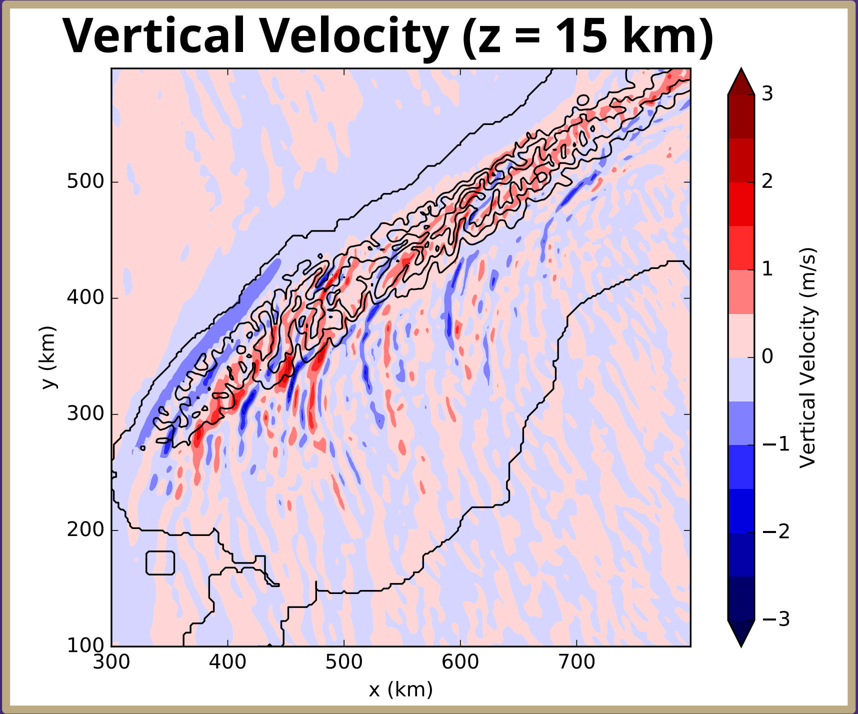




Directional Critical Level?

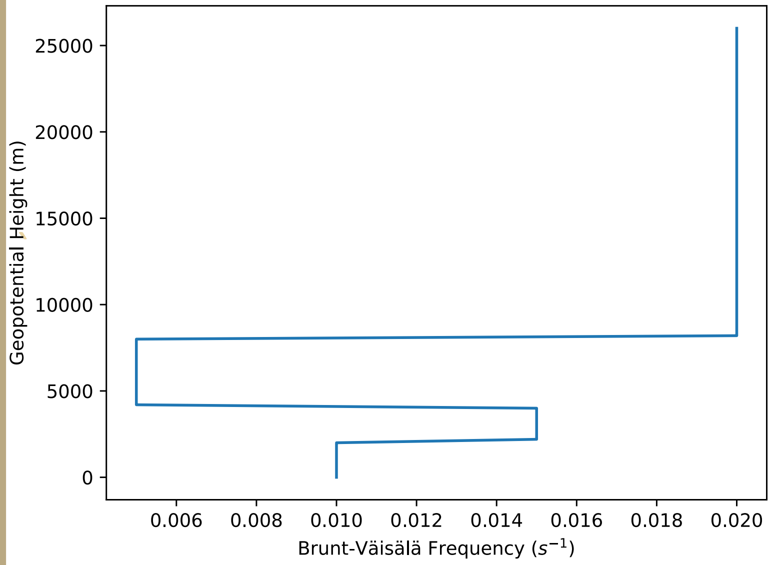


Doyle and Jiang (2006)

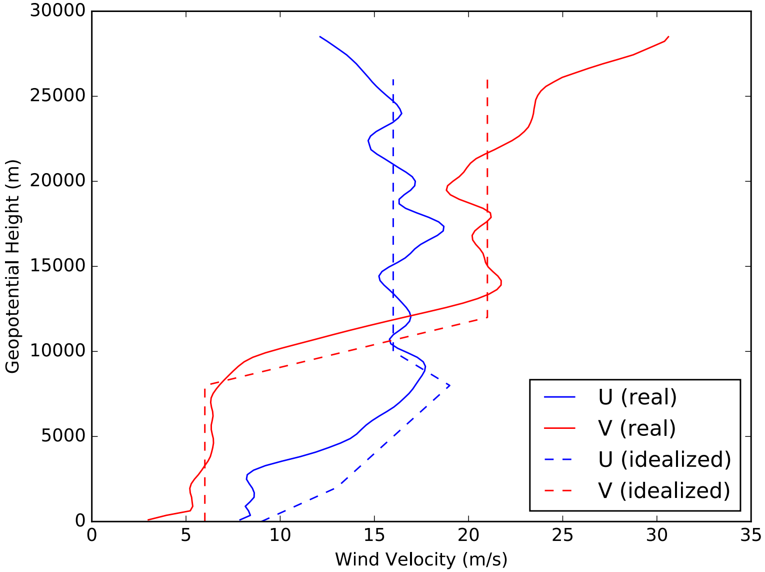


WRF Idealized Configuration

Idealized Static Stability

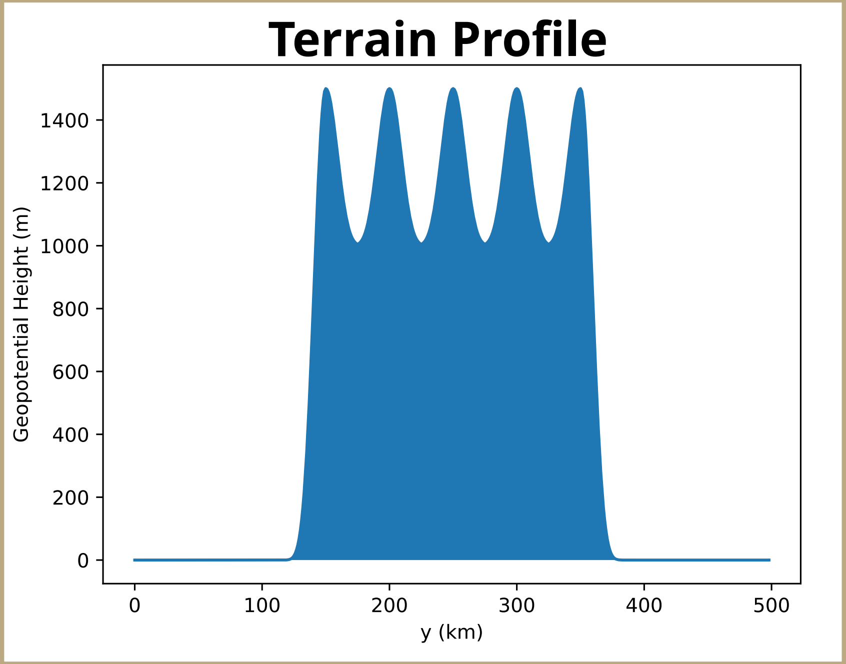


Real & Idealized Wind Profiles

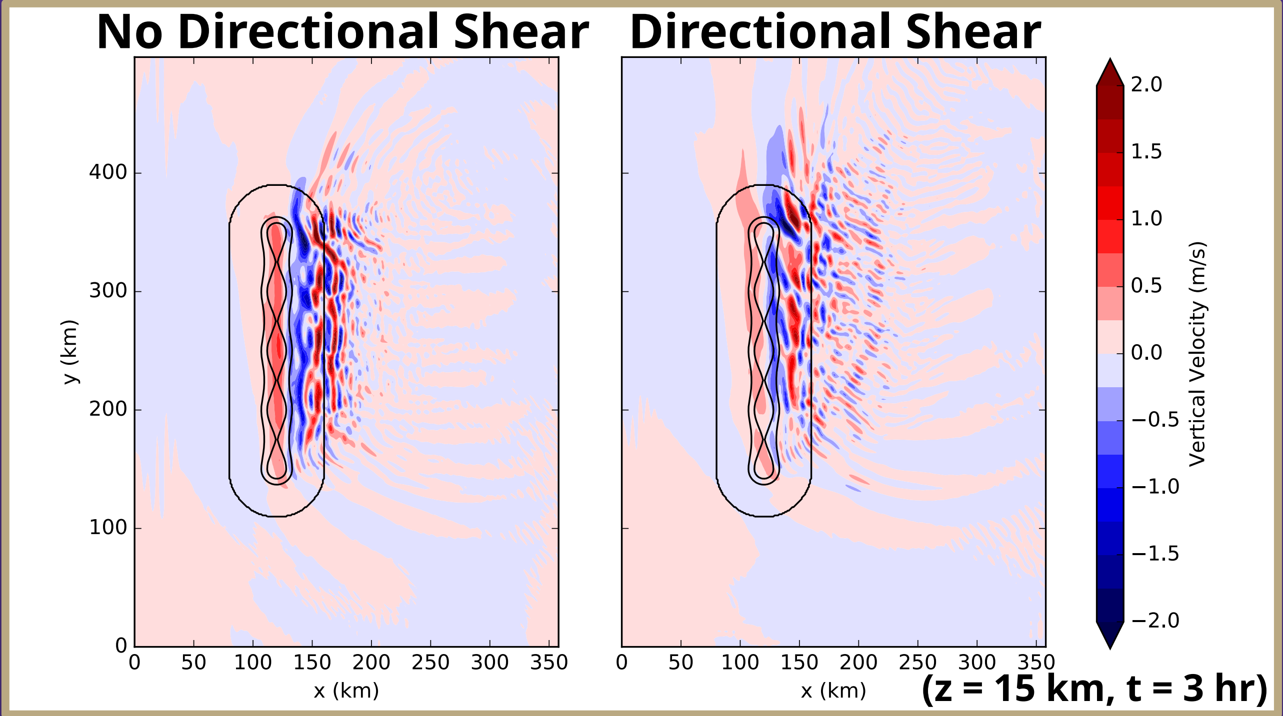


Idealized Terrain Configuration

> Five peaks on top of an isolated ridge



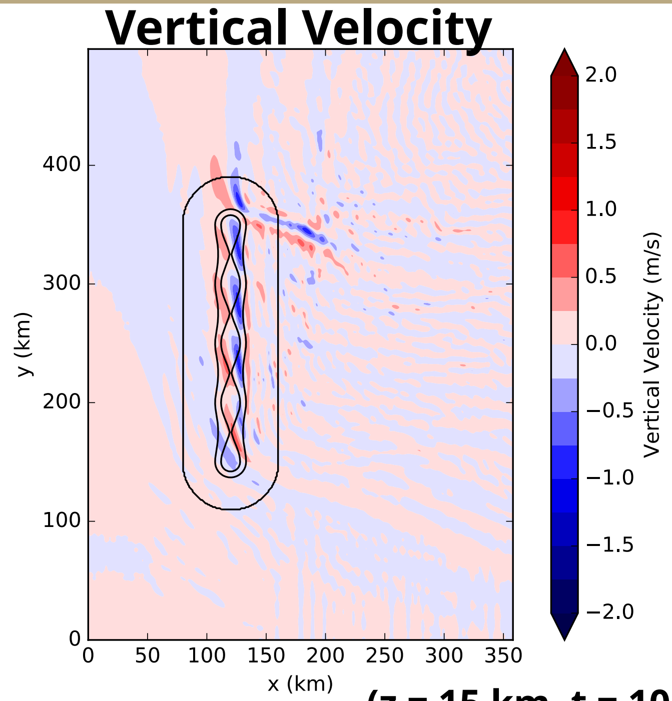
Ship Waves



No Directional Shear
Directional Shear
y (km)
x (km)
x (km)
0
100
200
300
400
0
50
100
150
200
250
300
350
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Vertical Velocity (m/s)
(z = 15 km, t = 3 hr)

Ship Waves

- Problem:
  - Waves are transient
  - Disappear almost completely by 10 hr



(z = 15 km, t = 10 hr)

Possibility #3

Possibility #3

- Waves are due to the lee-side ridges and valleys ✗
- Waves are trailing waves à la Jiang et. al. (2014) ✗
- Waves are one half of a ship wave pattern, with the other half destroyed by a directional critical level à la Doyle and Jiang (2006)

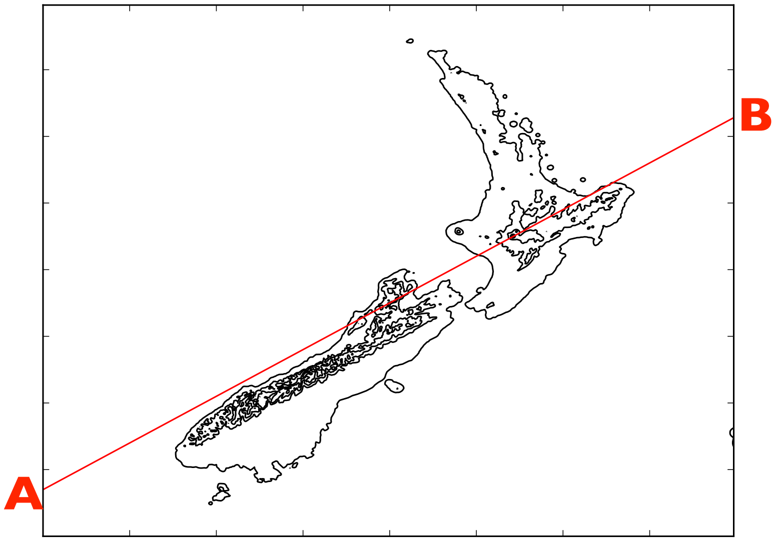
Possibility #3

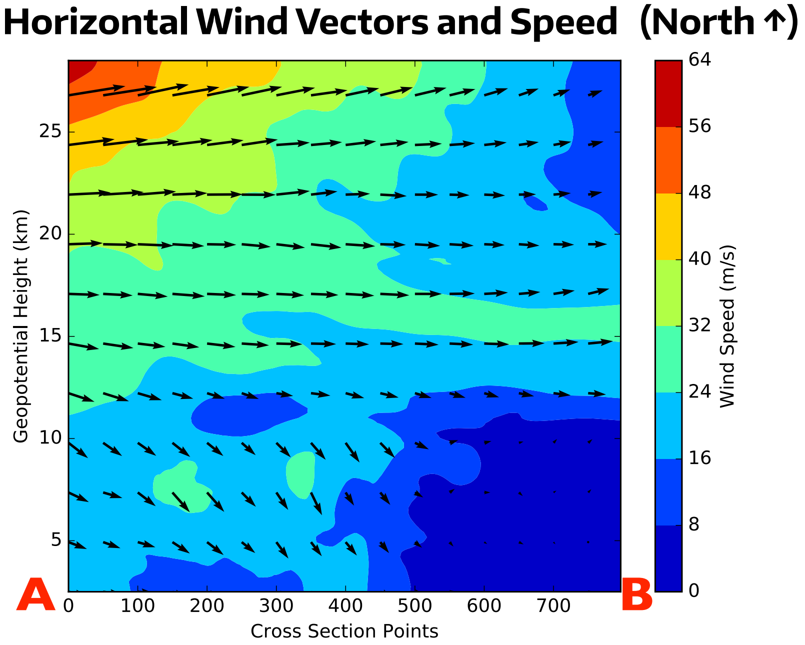
- Waves are due to the lee-side ridges and valleys ✗
- Waves are trailing waves à la Jiang et. al. (2014) ✗
- Waves are one half of a ship wave pattern, with the other half destroyed by a directional critical level à la Doyle and Jiang (2006) ✗

Possibility #4

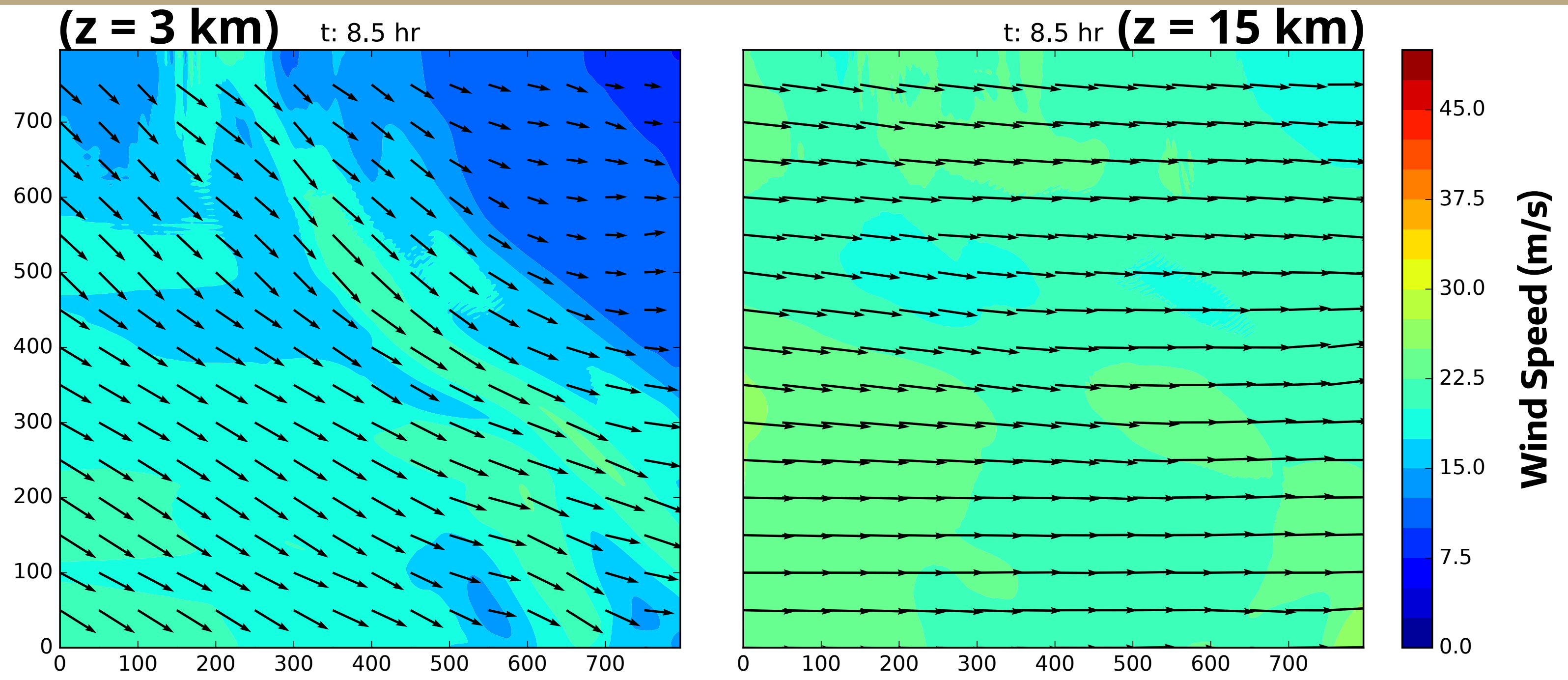
- ~~Waves are due to the lee-side ridges and valleys~~ ✗
- ~~Waves are trailing waves à la Jiang et. al. (2014)~~ ✗
- ~~Waves are one half of a ship wave pattern, with the other half destroyed by a directional critical level à la Doyle and Jiang (2006)~~ ✗
- **Horizontal variations in the wind field are important to the formation of the waves (through some as yet unexplained mechanism)**

Horizontally Heterogeneous Winds



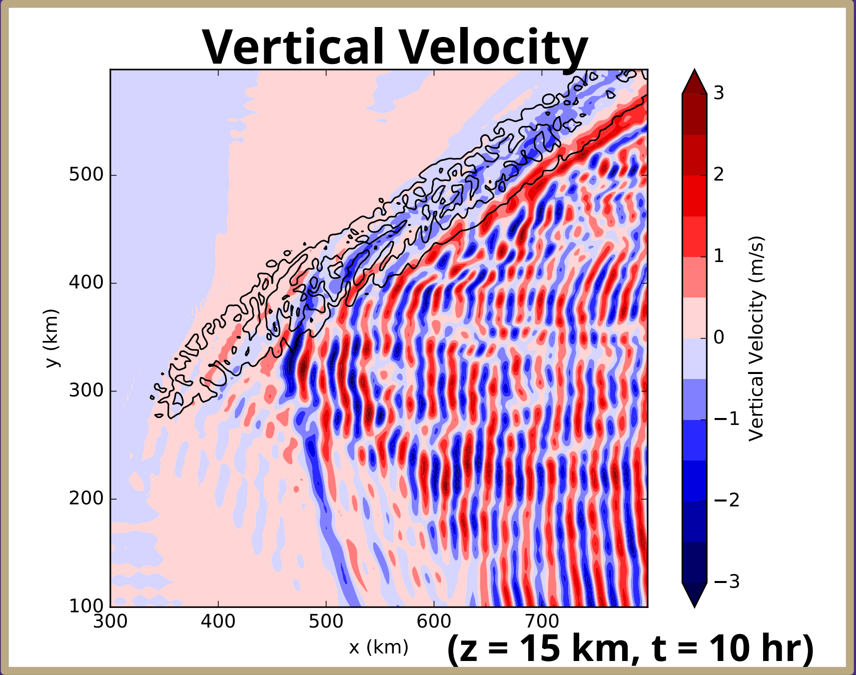


Horizontally Heterogeneous Winds



Horizontally Heterogeneous Winds

- We get the waves!
- Wind is essentially steady and non-divergent
- Therefore, something about the inhomogeneities in this wind field helps generate the waves

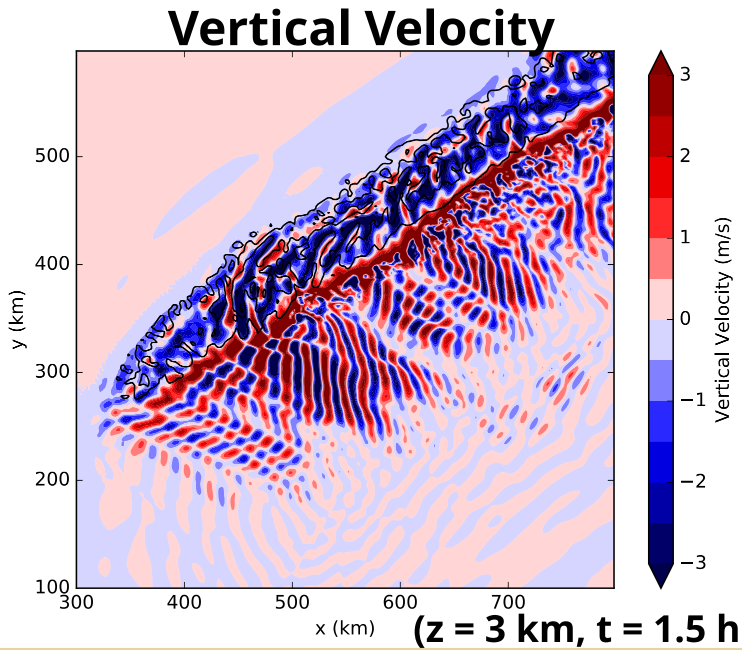


Some Notes…

- These waves are fairly low (~15 km)
- They appear in regions of little lateral shear
- Previous dynamical explanations require:
  - Either directional critical levels…
  - …or…
  - Large lateral shear
- Neither of which are present in this case

A Long Time Ago, On A Level Down Down Low

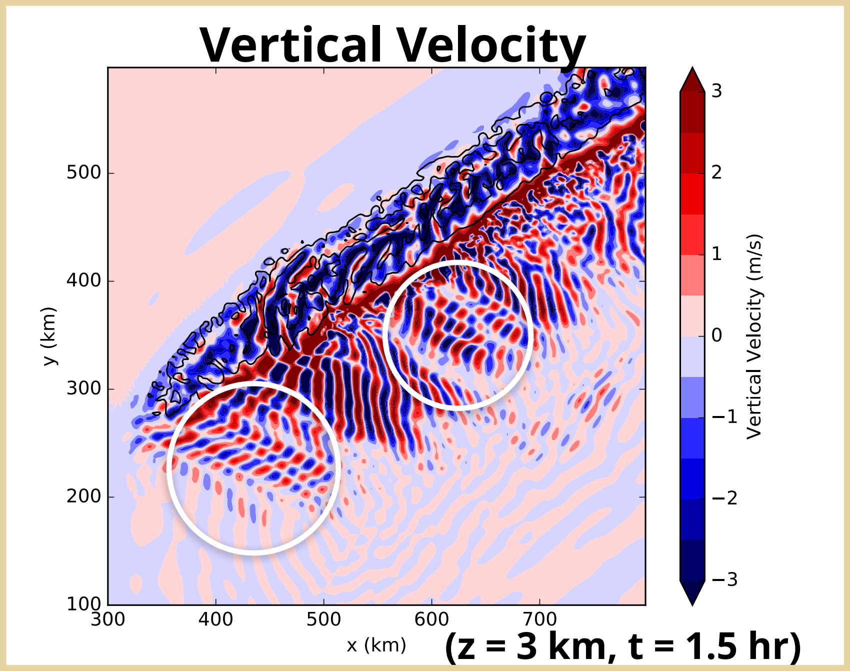
- Low-level trapped waves oriented SW-NE appear in the real simulations
- However, here the transverse waves also appear
- Is wave interference present?
- Are the SW-NE waves trapped, while the N-S waves can propagate?



(z = 3 km, t = 1.5 hr)

A Long Time Ago, On A Level Down Down Low

- Low-level trapped waves oriented SW-NE appear in the real simulations
- However, here the transverse waves also appear
- Is wave interference present?
- Are the SW-NE waves trapped, while the N-S waves can propagate?



Conclusions

- Horizontal inhomogeneities appear to be important
- However, none of the existing dynamical explanations are particularly well suited to explain this